PROPOSAL NUMBER: GC04-321

PROGRAM ELEMENT: Global Carbon Cycle Program

TITLE: An End-to-end Data Management System for Ocean pCO_2 Measurements.

A COLLABORATIVE PROPOSAL SUBMITTED to the
OFFICE OF GLOBAL PROGRAMS from

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DURATION: March 1, 2004 - February 28, 2007

BUDGET: $429,565	Year 1	Year 2	Year 3
NOAA/PMEL (including CDIAC)	$125,850	$129,267	$130,900
NOAA/AOML	$15,010	$14,021	$14,517

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ABSTRACT:

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An End-to-end Data Management System for Ocean pCO_2 Measurements

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ABSTRACT

Reliable and efficient data management within the NOAA Global Carbon Cycle Program will require standards and infrastructure to: upload/ingest new data; quality control data sets; provide users with timely access to data; and ensure its long-term archival. The October 2001 Carbon Data Management Plan, a product of the carbon data management workshop held at PMEL (Feely and Sabine, 2002), articulates a community consensus on the need for a systematic approach to ocean CO_2 data management. The ultimate objective of the plan is to provide the oceanographic community with easy access to high-quality near real-time CO_2 and related physical, chemical and biological data sets. The plan outlines the need for new standards regarding analytical measurement techniques, data formats, metadata content, quality control and assessment procedures. The plan recognizes that the data management system must build upon existing capabilities and must be compatible with the emerging standards for integrated ocean data management within the U.S. It identifies the Carbon Dioxide Information Analysis Center (CDIAC) as a regional quality control and data management facility and the Live Access Server from PMEL as a sound software foundation for the system. It also recommends the creation of a CO_2 Science Team and a Data Management Group to guide the creation of standards and the evolution of the data management system.

This proposal is a road map for the implementation of that data management plan as an end-to-end data management system, and a process for governance of that system under the CO_2 Science Team. The vision of the data system is of five integrated components coordinated through suite of data standards and procedures. The components are i) local QA/QC and the initial collation of shipboard data; ii) regional QC and assembly of data; iii) operational data base management; iv) the Web-based data access subsystem; and v) permanent archival. The steps to develop these components and the individuals and institutions that will build them are detailed in the proposal.

RESULT FROM PRIOR RESEARCH

NOAA - Pacific Marine Environmental Laboratory:

Steve Hankin is Chair of the Data Management and Communications (DMAC) Steering Committee, which is developing the plan for data integration within the US Integrated Ocean Observing System (IOOS). Within the DMAC Plan the Live Access Server (LAS) is identified as a recommended component for the implementation of IOOS. Recent systems based upon LAS include:

- The National Virtual Ocean Data System (NVODS) − a NOPP-funded effort to implement a general distributed data virtual "hub" for all ocean data. Within NVODS LAS provides a "guaranteed minimum" geo-referenced live access through a Web browser (see *http://www.ferret.noaa.gov/nopp/*).
- The Global Ocean Data Assimilation Experiment (GODAE) − infrastructure to improve ocean data assimilation and operational nowcast/forecast modeling. LAS is used within GODAE (*http://usgodae1.fnmoc.navy.mil/las/*) to provide real-time ocean observations and atmospheric model boundary conditions to modelers as well as collaborative sharing of outputs (*http://www.ferret.noaa.gov/godae/*)
- LAS is the primary user interface for the integrated US JGOFS data base (*http://synthesis.whoi.edu/mp-las/*)
- LAS forms the heart of the Facility for the Analysis and Comparison of Tsunami Simulations (FACTS) - a research system working towards the improvement of tsunami inundation forecasting (*http://ferret.wrc.noaa.gov/FACTS/*)
- LAS is in use by a great many groups outside of PMEL, both nationally and internationally. (See a table of LAS sites at *http://www.ferret.noaa.gov/LAS/LAS_servers.html*)

The PMEL and AOML CO_2 groups have worked together since 1990 to collect and analyze data from the NOAA/NSF/DOE Global CO_2 Survey cruises under the auspices of NOAA's Climate and Global Change (C&GC) Program. As part of this effort, we synthesized the CO_2 data from the Atlantic, Pacific and Indian Oceans into a unified self-consistent data set (Sabine *et al*., 1999; Feely *et al*., 1999; Lamb *et al*., 2002; Wanninkhof *et al.,* 2003), from which we have determined the distribution of anthropogenic CO_2 in the oceans (Sabine *et al*., 1999; Feely *et al*., 2001; Sabine *et al*., 2002; Lee *et al*., 2003); and the relative impacts of soft tissue remineralization and carbonate dissolution on the distributions of carbon species in surface and subsurface waters. (Feely *et al*., 2003; Sabine *et al*., 2002; Chung *et al*., 2003). The NOAA Office of Global Programs and the Department of Energy jointly funded the previous CO2 synthesis work. All of the suggested corrections for the Global CO_2 data sets are available at the GLODAP WWW site (http://cdiac.ornl.gov/oceans/glodap/Glodap_home.htm).

NOAA/OGP/OACES GC365; 9/1/02-9/30/04, Underway CO_2 Measurements on the NOAA Ships Ka'Imimoana and Ron Brown; R. Feely, R. Wanninkhof - In several papers Dr. Feely and coworkers have described the diurnal, weekly, seasonal, interannual and interdecadal variability of CO_2 distributions and fluxes in the equatorial Pacific (Cosca *et al*., 2003; Feely *et al*., 1994, 1995, 1997, 1999; 2002; submitted; Takahashi *et al*., submitted; Wanninkhof *et al*., 1995, 1996). Time-series data from the JGOFS experiment

indicate diurnal variations on the order of ± 8 µatm due to near-surface mixing processes (Feely *et al*., 1997). Weekly variations on the order of ± 15 µatm are due to the passage of tropical instability waves (Feely *et al*., 1994). Seasonal variations of ± 30 µatm are due to seasonal changes in new production (Cosca *et al*., 2003). Interannual variations, caused by ENSO forcing contribute to the largest changes in pCO_2 in the eastern Equatorial Pacific (Feely *et al*., 1995; 1997; 1999; 2002; 2003; Wanninkhof *et al*., 1995; 1996). Significant decadal changes due to the phasing of the PDO have recently been determined by Takahashi *et al*. (2003) as a significant change in the slope of the rate of change in the temperature-corrected pCO_2 as a function of time over the past two decades in the equatorial Pacific. In other papers by Boutin *et al*. (1999) and Etcheto *et al*. (1999) detailed descriptions of the interannual variability of the CO_2 fluxes have been provided for the 1990s.

GC99-220, 5/1/1999-4/30/2002, Synthesis and Interpretation of the NOAA/DOE Global CO_2 Survey Data; C. Sabine, R. Key, R. Feely, J. Bullister, R. Wanninkhof, T.-H. Peng, F. Millero, A. Kozyr - The central objective of this grant was to generate a unified data set from the global CO_2 survey cruises and to determine the global distribution and inventories of both natural and anthropogenic carbon species. Our first task was to assemble a quality controlled merged data set for each basin. The working data include all of the DOE survey cruises, all of the NOAA OACES cruises and as many international WOCE cruises as possible. Based upon extensive quality assessments the DIC and alkalinity data are believed to be accurate to ± 3 µmol kg^{-1} and ± 5 µmol kg^{-1}, respectively (Johnson et al., 1998; Millero et al., 1998; Sabine et al., 1999; Lamb et al., 2002, Wanninkhof et al., 2003). Gridded carbon fields are available to the public via the WWW <http://cdiac.ornl.gov/oceans/glodap/Glodap_home.htm>. Anthropogenic CO_2 has been estimated using the ΔC* approach in all three oceans (Sabine et al., 1999, Sabine et al., 2002a, Lee et al., 2003). Numerous other publications covering a broad range of carbon cycle issues have been published or are in preparation as a result of this project (e.g. Coatanoan et al., 2001, Feely et al., 2001, Orr et al., 2001; Sabine and Feely, 2001; Sabine et al., 2002b, Feely et al., 2002b; Millero et al., 2002). A CD atlas with all of the combined data sets (both bottle data and objectively gridded 3-D fields) is being generated for distribution to the community.

DOE - Carbon Dioxide Information Analysis Center:

CDIAC is a part of the environmental sciences division of Oak Ridge National Laboratory, a U.S. Department of Energy (DOE) facility. Among other things, CDIAC has provided data management support for Joint Global Ocean Flux Study (JGOFS) CO_2 measurements taken aboard research vessels during the World Ocean Circulation Experiment –World Hydrographic Program (WOCE-WHP) cruises. DOE sponsored CO_2 measurement operations and continues to sponsor CDIAC's data support activities, which include data archival, data checking and evaluation, preparation of data documentation, and data dissemination. Through the end of FY 2000, DOE-supported investigators had collected CO_2 measurements on 42 WOCE cruises. CDIAC has received data from all of these cruises, and all of these data sets have undergone quality assurance checks. CDIAC has compiled 21 numeric data packages (NDPs), which involved developing a rapport with a

variety of oceanographers both in the U.S. and abroad. Alex Kozyr single-handedly developed, and maintains, CDIAC's oceanographic home page (*http://cdiac.ornl.gov/oceans/home.html*), with links to all 21 electronic-readable NDPs, plus additional features that include links to the data and metadata. CDIAC has compiled the ODV-based CDIAC-WOCE collection that includes hydrographic, chemical, and CO_2-related measurements made on all WHP cruises during the last decade. This collection is available to the public through the CDIAC web page.

CDIAC provides data management support for the GLobal Ocean Data Analysis Project (GLODAP). GLODAP is a cooperative effort of investigators funded as a part of the JGOFS Synthesis and Modeling Project (JGOFS-SMP) to synthesize and interpret the global CO_2 survey data. Cruises conducted as part of the WOCE, JGOFS, and the NOAA Ocean-Atmosphere Carbon Exchange Study (OACES) over the decade of the 90s have generated oceanographic data of unparalleled quality and quantity. The synthesized GLODAP data set is available through the CDIAC web page at http://cdiac.ornl.gov/oceans/glodap/Glodap_home.htm. CDIAC is now heavily involved in several regional data synthesis projects like CARbon dioxide IN the Atlantic Ocean (CARINA) and the North Pacific Marine Organization (PICES). Through these efforts, CDIAC now holds the largest data base in the world for the oceanic CO_2-related measurements.

NOAA - Atlantic Oceanographic and Meteorological Laboratory:

AOML has managed data obtained from survey cruises funded by the OACES program since 1992. The last award was entitled: ``Data Management for the NOAA Ocean-Atmosphere Carbon Exchange Study" (NOAA CGC, 4/1/99 to 3/31/00, PIs Tsung-Hung Peng, James C. Hendee and Richard A. Feely.)

Major results from this work are data QC and data release to the public in connection with research objectives established by the OACES program. At the web site (*www.aoml.noaa.gov/ocd/oaces*), we have posted many resulting data sets. To support the current NOAA/DOE joint global CO_2 survey data synthesis and analysis program, we have made available the data sets from the NOAA CGC survey cruises in 1990, 1991, and 1992. We have also completed the quality assurance process for the newly obtained data in the North Atlantic basin along 24^{o}N in Feb. 1998, and the GASEX-98, a process study for CO_2 exchange across sea-air interface, along 48^{o}N in May and June 1998. A data report for the 24^{o}N cruise has been produced (Peltola et al 2001) and previous reports have been posted on the web site.

A new web site has been created for distribution maps of underway CO_2 partial pressure (pCO_2), collected on NOAA Ships *Baldrige*, *Brown*, *Ka'imimoana* and *Discoverer* since 1992 in the equatorial Pacific (*http://www.pmel.noaa.gov/CO_2/CO_2-home.html*). The maps include surface water pCO_2 values, as well as CO_2 fluxes for the equatorial Pacific. All data from the Baldrige and Brown are posted on the AOML web site (*http://www.aoml.noaa.gov/ocd/oaces/mastermap.html*). Data from the Brown are currently posted within 2 months from the date of collection.

STATEMENT OF WORK

Statement of the Problem:
In October 2001 the NOAA Office of Global Programs commissioned a workshop at NOAA/PMEL to outline the requirements for data management of the ocean component of the Carbon Cycle Science Plan. Potentially very large numbers of oceanic CO_2 and related observational data must be quality controlled, ingested, archived, and made available to the community (Feely and Sabine, 2002). The workshop participants drafted a plan (http://www.ogp.noaa.gov/mpe/gcc/pdf/noaadatamanageplan.pdf) that included data policy, institutional arrangements, and mechanisms for dealing with new and historical oceanic CO_2 data sets. The ultimate objective of the plan is to provide the oceanographic community with easy access to high-quality near real-time CO_2 and related physical, chemical and biological data sets. The plan also outlined the need for a CO_2 Science Team with responsibility for defining standards regarding analytical measurement techniques, data formats, metadata content, quality control and assessment procedures, and the steps to be followed for post-processing data.

With respect to underway measurements the plan outlined procedures that would provide rapid availability of calibrated data of a known quality, even as the number of measurement systems supplying such data increases with time. It was recognized that achieving this rapid turnaround will require investments in data management system development (as well as automated instrumentation). The plan emphasized that the data must be made available, not only on fixed media such as CD-ROM, but also on the Web, which is likely to be the primary method of data delivery over the lifetime of the program. The interface to the data on the Web must address a broad community, including scientists and educators that lie outside of the immediate ocean carbon data measurement community. The Web interface should provide i) uniformity across multiple versions (age and QC level) of the data; ii) both "large-scale" subsetting and "per cruise" subsetting; and iii) a suite of graphical "browsing" and comparison tools. The Live Access Server (LAS) was identified as a suitable system that could be expanded to meet these needs.

The plan concluded that national data centers, such as the Carbon Dioxide Information Analysis Center (CDIAC), should be centrally involved in the data management process. The representative of this center should participate in the CO_2 Science Team meetings and provide assistance in the quality assessment/quality control (QA/QC) of data. Regional QC of the data will be primarily performed by CDIAC. The plan specified the need for two complimentary organizations/facilities for the processing and archival of carbon data and related parameters: CDIAC, which would provide a medium to long-term/permanent repository for carbon data, and the US World Data Center A for Oceanography (NODC/WDC A) to serve as the permanent data archive for the data.

Proposed Solution

We propose to create an end-to-end integrated data system that will meet the needs identified in the October 2001 Carbon Data Management Plan. The vision of the data system is of five integrated components, which will be briefly summarized in this section and then described in greater detail under the **Detailed Work Plans, by institution** section of this proposal. Organizationally, the co-PIs of this joint proposal define the core of the Data Management Group as discussed in the Data Management Plan.

1. Local QA/QC and the initial collation of shipboard data will take place at several locations -- at AOML, PMEL, and other laboratories -- each associated with PIs involved in making the CO_2 measurements. These activities are the first stage of data management to follow shipboard collection. The local QA/QC activities will involve intercomparison exercises as necessary to ensure highest-quality measurements. Measurement protocols will be harmonized among contributors in concert with this stage of QA/QC. The timeliness requirements for transfer of locally QC-ed data to the regional QC center (to be adopted by the CO_2 Science Team) will be an important constraint for the local QC and collation activities.

2. Regional QC and assembly of data will be the responsibility of CDIAC with guidance from the CO_2 Science Team. Locally QC-ed data must be submitted to CDIAC using standards to be developed by the Data Management Group and CO_2 Science Team. The standards will emphasize tight integration of data and metadata, utilizing file formats that are in effect self-describing data objects for underway measurements (e.g. including ship_name, cruise_id, PI_name, instrument_type, etc.) Automated QC procedures will be developed by CDIAC to facilitate rapid (ideally 48 hour) public availability of data once submitted. Quality-Controlled data, once examined by CDIAC, will be ingested into the operational data base.

3. Operational data base management will be the responsibility of CDIAC. In addition to data security and integrity, data base management includes i) summary report generation; ii) developing and maintaining a metadata data base through which data are closely linked to the associated documentation; iii) production of CD-ROMs compatible with desktop analysis systems such as Ocean Data View (ODV); and iv) transfer of data to the permanent archive at NODC, including periodic time-stamped snap shots. While CDIAC will have responsibility for maintaining the data base, responsibility for the development and evolution of the data base (software strategies) will lie largely with PMEL.

4. The data access subsystem: The design considerations for the data base to be developed by PMEL include high reliability, easy updating, rapid queries based upon space-time regions and constraints such as cruise ID, and version control that recognizes the need for scientifically reproducible retrieval of previous versions of the data collection. Web-based data visualization, subsetting, and comparison capabilities, will work in concert with the operational data management subsystem. The access subsystem will provide an interface through standard Internet Web browsers (e.g. Internet Explorer) that will allow a range of users, including scientists outside of the carbon cycle research community i) to obtain

quick custom plots; ii) to obtain self-documenting data subsets usable by desktop applications (e.g. ODV and Excel); iii) to make comparisons between repeat sections and gridded fields; and iv) to merge on-the-fly and evaluate US holdings against international partners. The design will build upon the successful Live Access Server (LAS). The operational carbon-LAS server will be hosted and maintained at CDIAC.

5. Permanent data archival and the creation of reference data products, which may include merging of US data with international/historical data sources, will be achieved through submission of the data to NODC. Integrated data sets from NODC will be made available on-line and on durable media. Permanent archival of the "pure" US carbon data collection will also be the responsibility of CDIAC.

At present there is no formal CO_2 Science Team for NOAA's underway pCO_2 program. An ad-hoc group of pCO_2 PIs funded under NOAA's VOS program has already met in Miami in October of 2002 to discuss design strategies. This group is being organized by Rik Wanninkhof and continues to communicate informally through email. The Data Management Group will work closely with this ad-hoc group to facilitate the implementation of the program outlined above. Once the official Science Team is assembled, the Data Management Group will establish formal collaborations with the group and participate in the Science Team meetings.

Detailed Work Plans, by institution:

NOAA/PMEL:

Steve Hankin will have primary responsibility for the design, implementation, and evolution of the software that will manage the US ocean carbon data collection and provide Web access to it. Richard Feely will serve as scientific liaison throughout the development of the data management system. Hankin, Feely and members of their research groups will help in the specification of requirements, testing, and evaluation of the data management system as it evolves. Feely and Hankin will also act as official liaisons with the CO_2 Science Team to ensure that both groups are working together as efficiently as possible.

The PMEL group must ensure that the systems developed for ocean carbon data are broadly interoperable with other national and international ocean and climate data systems. PMEL's leadership role in major national ocean data management efforts make it well suited to this task (see **Results from Prior Research**). Two subsystems must be created for the ocean carbon data system - the **data access subsystem**, and the **data management subsystem**.

Data access subsystem

The data access subsystem will build upon the PMEL-developed Live Access Server (LAS; see *http://www.ferret.noaa.gov/LAS*). LAS is designed as a software "traffic-cop" - it routes requests from Web users to various "back end" applications and data bases that then subset the data and produce formatted files and graphics. LAS has demonstrated its ability to meet the needs of several related data communities. A prototype Carbon-LAS data access subsystem for underway measurements has been previously demonstrated at PMEL.

The new Carbon-LAS will be enhanced in many ways with respect to this primitive prototype:

- The ability of the user to constrain the data selection based upon metadata parameters such as PI_name, cruise_id, or instrument_type will be added;
- The ability to make comparison between cruise tracks and gridded data products will be added;
- Specialized visualization techniques suitable for the display of underway cruise measurements, including integrated presentation of metadata, will be developed;
- The ability to merge data on-the-fly from multiple sources will be added, so that the scientific value added by including foreign collections can be quickly assessed.

Two types of data subsetting of the carbon data collection will be provided for users: (1) large-scale subsetting in which the entire holdings for a particular group of parameters may be queried based upon constraints such as latitude-longitude-depth ranges, date range and/or seasonality; and (2) per cruise subsetting, in which users recover the measurements from a particular cruise. Downloaded subsets will be made available in a user-specifiable choice of formats. The list of output formats to be supported will address the range of applications commonly used by interested communities (e.g. Matlab, Excel, ODV, OceanAtlas, Ferret, etc.). The list will be expanded as needed to accommodate new ocean analysis applications.

Carbon-LAS will combine the (new) handling of underway measurements with the (existing) ability to handle gridded data sets (model outputs and climatological products.) It will provide immediate feedback to users on when and where measurements are available. It will enable users to make quick comparisons of repeat sections, underway tracks, and cross-over points. It will enable a user to evaluate changes to the data between versions of the US collection.

Data management subsystem

Several prospects exist for the development of the data management subsystem. To meet the short term project needs a data management subsystem will initially be developed, which is based upon netCDF files. This approach, while successful in several LAS systems, is not optimally suited to the requirement for continual updates of the carbon data. Thus the alternative approaches described below will also be explored. PMEL will develop techniques that integrate scientific variables and metadata. It will be the responsibility of CDIAC, in consultation with PMEL, to configure the system to address the full range of specific carbon-relevant variables and metadata that must be supported and to manage the systems in an operational mode. Thus, the data management subsystem will be a partnership between PMEL, CDIAC, and AOML.

The following candidates for a data management system will be evaluated. The selected approach developed into an operational system.

1. Relational data base management systems offer the highest level of flexibility, but at greater complexity than alternatives. The free relational data base management systems, MySQL and Postgress, are both sufficiently powerful to handle the anticipated size and

access requirements of the carbon data collection. Commercial data base management systems will also be considered.

2. The National Virtual Ocean Data System (NVODS) is developing aggregation technology that allows collections of individual files to be accessed as a consolidated virtual data set. Using these aggregation techniques each underway cruise leg could be stored as an individual netCDF file, while the full collection remained usable for high level data queries. This approach offers great flexibility and simplicity, however, the performance of the NVODS aggregation server is unproven.

3. The netCDF file techniques that will be employed as the near-term solution can be extended to support easy updates of new data. The netCDF file techniques are known to satisfy the performance and reliability requirements of the project. We list this as our final alternative because there are significant labor costs associated with developing and maintaining custom code of this type.

PMEL Deliverables:

- Carbon-LAS data access subsystem
- Carbon data management subsystem

References (PMEL):

Hankin, S. and the DMAC Steering Committee, 2003, The US Integrated Ocean Observing System (IOOS) Plan for Data Management and Communications (DMAC), Ocean.US, Arlington, VA (*http://www.dmac.ocean.us/*)

Hankin, S., P. Cornillon, et. al. (2002): NVODS: Data Networking for an Integrated Ocean Observing and Prediction System. 18th Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, AMS, 13-17 January 2001, Orlando, FL 242–244.

Hankin, S., J. Sirott, et. al. (2002): Live Access Server: A Tool for Web Access to *in situ* Data Collections, too. 18th Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, AMS, 13-17 January 2001, Orlando, FL J55-J56.

DOE/CDIAC:

CDIAC will have primary responsibility for processing and maintaining the regionally quality controlled research-quality data sets. CDIAC will develop the automated underway data processing system and will manage the operational data management subsystem and the carbon-LAS data access subsystem that are developed by PMEL.

Data Collection and Submission

As per the October 2001 Carbon Data Management Plan it is assumed CDIAC will receive locally QC-ed data within an agreed time interval following the point that it "reaches dry land". At this point the data will be in the standardized interchange file format, with uniform metadata conventions and complete metadata (as defined by the Data Management Group and CO_2 Science Team) CDIAC will ingest this data into its data base and make it

available via carbon-LAS within two days, flagged as having been QC-ed at the local level, only.

Automated Underway Data Processing

Data Submission

Data will be transferred regularly to CDIAC from the local QC groups in one of two ways: i) CDIAC will establish a secure location in the /incoming area on the CDIAC FTP server (cdiac.ornl.gov) where files may uploaded; and ii) CDIAC will "mirror" other FTP servers to accomplish data transfers at regular intervals.

QA/QC

Basic regional QA/QC of all underway measurements will be handled in an automated fashion. The CDIAC host system will run regularly scheduled scripts that copy original files to work areas, execute SAS computer programs, generate summary outputs, and copy results files to locations on the CDIAC file system. The SAS codes will identify missing metadata fields and data file formatting errors and will generate simple summary statistics (i.e. minimum, maximum, mean, and standard deviations) and time-series plots for all measurement parameters. Cruise tracks will be plotted routinely and in cases where the return legs overlap the outgoing leg, both legs will be compared for each parameter. All plots and statistics will be reviewed by Alex Kozyr and also made available on the CDIAC Web site. Any errors or suspicious values identified by the CDIAC QA/QC procedures will be corrected, either directly in obvious cases or after consultation with the data submitters. Additional "regional" QA/QC procedures will be added over time to the automated processing under the direction of the CO_2 Science Team..

Collation of Data Streams

The SAS codes described previously will read the files that have been submitted and create SAS data sets for each ship and voyage. The data sets will then be ingested into the carbon data management subsystem developed by PMEL and configured by CDIAC, from which it will immediately be available to the public via carbon-LAS.

Integration of Underway Measurements and Metadata

A good deal of what has traditionally been thought of as "metadata" will be regarded as (required) variables in the data sets, and will be handled by the data management subsystem and the carbon-LAS. This includes simple string variables such as ship_name, cruise_id, and PI_name. The design of the data interchange formats will guarantee that data measurement groups must include these "variables", or the files that they submit will be regarded by the systems as incomplete. Other associated metadata, text documents such as cruise logs, however, may be submitted as separate files and CDIAC will maintain a Web-based system for access to these records, linked to their respective data sets.

Delivery of Underway Data to Researchers and the General Public

Data will be made available to users via three mechanisms: carbon-LAS, FTP, and durable media (CDROM). Via carbon-LAS a user may request specific subsets ("large-scale" requests by latitude-longitude-time and "per cruise" requests) and obtain either quick visualizations or data files in a choice of application-friendly formats (ODV and Excel will

be among the supported applications.) The user will also be able to perform limited data comparisons and evaluation via carbon-LAS. Via FTP a user may download single cruises as ASCII delimited files or the entire data base as an ODV data set. The same files available via FTP will also be made available on CDROM. CDIAC will offer worldwide distribution of the ocean-basin underway measurement databases as a Numeric Data Package (NDP) to any interested person without charge. The NDPs will be made available as hard copy publications that are mailed to requestors and as HTML documentation that are accessible via the Internet.

Permanent Underway Data Archival

CDIAC will store all underway measurements, along with all companion documentation and metadata, on the CDIAC Computing System. The size of the underway database is anticipated to be Order(gigabyte) by the end of the three year period of this proposal. CDIAC oceanographic data holdings are currently stored short-term on a 600 GB Redundant Array of Independent Disks (RAID) system and digital linear tapes, and are stored long-term on digital linear tapes and CD-ROMs. The National Oceanographic Data Center (NODC) is the official permanent data archive and will incorporate the final underway measurements into NODC's World Data Base collection. CDIAC will notify NODC by electronic mail whenever updates or changes are made to final underway data files.

NOAA/AOML:

The critical link between the production of field measurements and the availability of useful data for scientific research is the efficient data QC process and subsequent prompt dissemination of quality data to the research community. To achieve this we must have the following data quality controls: (a) improvement of present shipboard data management and QC capabilities, (b) improvement of existing post-cruise QC protocols, and (c) uniform standards for reporting data and metadata. AOML will provide a leadership role in the Data Management Group ensuring that these standards and protocols are defined in a timely manner and presented to the CO_2 Science Team for approval.

The following is the proposed solution for Data Quality Control

(a) **Improvement of present on board data management and QC capabilities.** Careful inspection of shipboard data sets enables the CO_2 Scientist to make decisions as to any changes in procedures that are needed, since collection of identical samples at a later time could never be accomplished. AOML will provide leadership in the definition of uniform adaptive procedures to be followed by scientists on research cruises and technicians on VOS cruises to ensure the quality of underway measurements.

(b) **Improvement of existing QC protocols**
Programmers and information specialists at AOML have devised a data range-checking algorithm and a sophisticated expert system has been devised (Hendee, 1995a and 1995b) for screening data in the master databases against parameters, which have been measured in the same area by previous cruises. Also, feedback

mechanisms have been developed to ensure reliable ingestion of data into the master data base. This experience will be applied in developing community consensus on QC procedures to be followed for all underway measurements.

(c) **Uniform data and metadata reporting requirements.**
Working closely with the CO_2 Science Team, AOML will play a central role in defining the standardized data formats for uniform data reporting and the minimum metadata reporting requirement.

AOML Milestones and Deliverables

- Achieving community consensus on improved automated data quality checking protocols
- Achieving community consensus on procedures for data reduction and quality control from underway systems to fulfill shipboard data quality criteria
- Achieving community consensus on appropriate formats and metadata standards for delivery of data to the regional QC site
- Participation in the development of regional QC procedures to be applied at CDIAC

References (AOML):

Hendee, J. Ocean profiler: Software for the at-sea merging of oceanographic data. NOAA Technical Memorandum, ERL AOML-86, 1995a.

Hendee, J. Operations manual for Pelagos: An expert system for quality control and feature recognition of oceanographic data from the open ocean. NOAA Technical Memorandum, ERL AOML-87, 1995b.

Peltola, E., K. Lee, R. Wanninkhof, R. Feely, M. Roberts, D. Greeley, M. Baringer, G. Johnson, J. Bullister, C. Mordy, J.-Z. Zhang, P. Quay, F. Millero, D. Hansell, and a.P. Minnett, Chemical and hydrographic measurements on a climate and global change cruise along 24 N in the Atlantic, WOCE section A5R(epeat), during January-February 1998, NOAA Data Report OAR AOML-41,pp. 199, AOML, Miami, 2001.

BUDGET JUSTIFICATION

PMEL Budget Justification (including CDIAC):

The PMEL budget includes three separate activities: 1) software/system development at PMEL (Hankin), 2) scientific liaison at PMEL (Feely), and 3) data management at CDIAC (Kozyr) The CDIAC budget has been included under PMEL for reasons of accounting simplicity at DOE/ORNL.

Personnel costs include 1.5 month/year for PI (Hankin) and 9 months/year in aggregate for LAS system developers. System development is split among three individuals who are respectively in charge of 1) fundamental enhancements to the system architecture (Rogers); 2) management of the shared computer code (bug fixes, UI changes, etc.) and development of new output products (graphics and data subsets) (Callahan); and 3) sysadmin and configuration to specifically address needs identified by the scientific liaison (Mclean). The scientific liaison (testing, quality assurance and feedback) is provided jointly by Feely (at no cost) and 1 month/year for Greeley. Overhead rates are computed at approximately 41% for all personnel, as detailed in the PMEL budget.

Kozyr's salary is covered by DOE. Travel for CDIAC includes one trip per year for Kozyr to consult with LAS developers at PMEL and Rik Wanninkhof at AOML on underway data QC/QA and data archival; one trip for Kozyr to attend the annual data management meeting; and one international trip. Yearly travel for LAS developers includes one trip for an LAS developer to meet at AOML or CDIAC and one trip for the PI to attend the annual data management meeting. Travel for the scientific liaison supports attendance by Feely at the annual data management meeting.

Equipment expenses include the purchase of a small server system in the first year, which will be used for software development and for hosting and testing of software before delivery to CDIAC. In the second year additional storage capacity and software as needed for database development are added to the server at PMEL. Publication costs at CDIAC cover the expenses of producing and distributing the NDP's as well as science team reports.

Computing Costs reflect internal charges within PMEL. Costs are pro-rated according to the number of person-months, reflecting both per person and per desktop charges in the PMEL laboratory algorithm. Additional fixed charges are included to cover hosting a Web server with Internet ports (FTP, HTTP) at PMEL.

AOML Budget Justification:

The budget reflects efforts and cost for part time support of a technical support individual. There is no salary support requested for the PI. The principal investigator, Peng, will be involved in improving data QC procedures, contacting PI's for data related concerns, assisting in data QC and conducting data analysis. Huss will carry out the daily data QC procedures and be responsible for data transmission to CDIAC for local and regional QC processes. Travel funds are requested for PI to present results of data analysis at national meetings and for visiting other data centers for resolving potential problems relating to data

quality assurance. The costs for expendable equipment, computer service and software will be used to support data analysis.

PMEL BUDGET

		2004 (Y1)		2005 (Y2)		2006 (Y3)	
Direct Labor		Mnth		Mnth		Mnth	
NOAA Salary							
PI	Hankin	1.5	15,681	1.5	16,730	1.5	17,232
CO-I	Feely	1.0	0	1.0	0	1.0	0
Tech Liaison	Greeley	1.0	6,836	1.0	7,109	1.0	7,394
JISAO Salary							
LAS devel 1	Callahan	3.0	14,391	3.0	14,967	3.0	15,566
LAS devel 2	McLean	3.0	8,629	3.0	8,974	3.0	9,333
LAS devel 3	Rogers	3.0	16,322	3.0	16,975	3.0	17,654
NOAA Benefit @ 22.3% of Sal+Lv			5,021		5,316		5,491
JISAO Benefit @ 24.5% of Sal			9,639		10,024		10,426
TOTAL SALARY & BENEFITS		**12.5**	**76,520**	**12.5**	**80,096**	**12.5**	**83,096**
Permanent Equipment			3,000		2,000		0
Other Direct Costs							
Travel							
	LAS developers		2,000		2,000		2,000
	Feely		1,000		1,000		1,000
	CDIAC		4,000		4,000		4,000
Supplies & Materials							
	LAS developers		1,000		1,000		1,000
	PMEL liaison		1,337		890		426
Publications							
	CDIAC		1,500		1,500		1,500
PMEL Computing							
	LAS developers		6,125		6,125		6,125
	PMEL liaison		1,500		1,500		1,500
TOTAL OTHER DIRECT COSTS			**18,462**		**18,015**		**17,551**
Indirect Costs							
F&A/NOAA 41% of Base			9,232		9,774		10,096
F&A/JISAO 26% of Sal+Ben			12,735		13,245		13,774
F&A/JISAO 15% of Sal			5,901		6,137		6,383
TOTAL INDIRECT COSTS			**27,868**		**29,156**		**30,254**
YEARLY TOTALS			**125,850**		**129,267**		**130,900**

AOML Budget

FTE Personnel	mm	$K	mm	$K	mm	$K
PI (Peng)	1	0.00	1	0.00	1	0.00
B. Huss	1	5.69	1	6.03	1	6.39
Total Salaries		**5.69**		**6.03**		**6.39**
Fringe Benefits						
23% NOAA		1.31		1.39		1.47
Total Salaries and Fringe Benefits:		**6.99**		**7.41**		**7.86**
Equipment						
Computers		2.50		0.00		0.00
		2.50		**0.00**		**0.00**
Travel						
Scientific Meetings		2.00		3.00		3.00
		2.00		**3.00**		**3.00**
Other						
operational supplies		1.15		1.10		1.00
		1.15		**1.10**		**1.00**
Indirect Costs						
33.83% NOAA		2.37		2.51		2.66
TOTAL		**15.01**		**14.02**		**14.52**

Vitae **Steven C. Hankin**

Professional Committees

2002-present	Chair, Data Management and Communications Steering Committee for the US Integrated Ocean Observing System
2001-present	Executive Committee of National Virtual Ocean Data System
2001-present	UCAR (NCAR) THREDDS Technical Task Force
2001-present	American Meteorological Society
1999-present	US GODAE Steering Committee
1995-98	NOAA/ESDIM NOAAServer core development team
1994-98	NOAA High Performance Computing and Communications committee
1989-93	American National Standards Institute, Computer Graphics Committee, X3H3

Current Research and Development Activities

- **U.S. Integrated Ocean Observing System (Ocean.US IOOS) –** leading the design and planning for data communications within the US Integrated Ocean Observing System
- **U.S. National Virtual Ocean Data System (NVODS) –** contributing to an "integrated ocean observing system" in which LAS is the common visualization tool
- **U.S. Joint Global Ocean Flux Study (JGOFS) –** developing an LAS-based data access system for the JGOFS data base jointly with the JGOFS project office
- **U.S. Global Ocean Data Assimilation Experiment (GODAE) –** developing data access systems for assimilation data streams and a collaborative comparison of model outputs
- **Facility for the Analysis and Comparison of Tsunami Simulations (FACTS) –** developing a data sharing system for distributed tsunami researchers and disaster managers
- **NOAA Geophysical Fluid Dynamics Laboratory (GFDL) –** providing GFDL with state of the art systems for access to and analysis of model-generated data
- **NOAA Operational Model Archive and Distribution System (NOMADS) –** developing a distributed system to deliver meteorological model outputs and observations to users
- **Carbon Modeling Consortium (CMC) –** providing a system for collaborative access to and comparison between global carbon cycle models and relevant observations
- Developing a system for distributed access to locale-specific nowcast/forecast model outputs for the use of **NOAA's Hazardous Materials (HAZMAT)** branch

Honors and Awards

2003	NOAA Technology Transfer Award
2001	NOAA Research Employee of the Year
1999	NOAATech2000 award for LAS: "an outstanding achievement in HPCC technology"
1998	NOAA Administrator's Award for Ferret: "an extraordinary contribution to information technology"
1998	NOAA Bronze medal for contributions to the NOAAServer System
1986-98	Ten NOAA Performance and Special Act Awards
1983-84	Boeing Fellowship for graduate study
1976-77	Thomas J. Watson Graduate Fellowship
1975	Phi Beta Kappa membership

Education

1984 M.S., Applied Mathematics, University of Washington, Seattle, WA
1975 B.A., Physics, Reed College, Portland, Oregon

Professional History

1984- Computer Scientist, NOAA Pacific Marine Environmental Laboratory, Seattle, WA
Major accomplishments include the development of:
- the Ferret program, an analysis and visualization of ocean/climate data, which is used in hundreds of research Labs internationally
- the Live Access Server (LAS), a Web-based visualization and data access system which has become a critical component for projects throughout the ocean research community

1983-84 Research assistant, University of Washington, Seattle, WA
Developed a model of the contribution of tree roots to soil shear strength under funding from the US Forest Service

1978-82 Computer Specialist, Redwood Sciences Laboratory, U.S. Forest Service, Arcata, CA
System manager, software developer, and group leader for a computer center at a small research laboratory.

1975-76 Thomas J. Watson Fellow, University of Western Australia, Perth, Western Australia
Independent study on the electrical charge from jet drops emitted by bursting bubbles

Selected Publications

Hankin, S. and the DMAC Steering Committee, 2003, The US Integrated Ocean Observing System (IOOS) Plan for Data Management and Communications (DMAC), Ocean.US, Arlington, VA (*http://www.dmac.ocean.us/*)

Hankin, S., J. Sirott, et. al. (2002): Live Access Server: A Tool for Web Access to *in situ* Data Collections, too. 18th Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, AMS, 13-17 January 2001, Orlando, FL J55-J56.

Hankin, S., J. Gallagher, and P. Cornillon (2000): An overview of the Distributed Oceanographic Data System (DODS). In Proceedings of the International Conference on The Ocean Observing System for Climate, 18-22 October 1999, Saint-Raphael, France, Poster Session B, 2 pp.

Hankin, S., D.E. Harrison, J. Osborne, J. Davison, and K. O'Brien (1996): A strategy and a tool, Ferret, for closely integrated visualization and analysis. *Journal of Visualization and Computer Animation, 7*, 149-157.

Vitae – Richard A. Feely

a. Professional Preparation

B.A.	University of St. Thomas	Chemistry	1969
M.S.	Texas A&M University	Oceanography	1971
Ph.D.	Texas A&M University	Oceanography	1974

b. Appointments

Research Assistant, Oceanography, Texas A&M University	1969-1973
Research Associate, Oceanography, Texas A&M University	1973-1974
Oceanographer, National Oceanic and Atmospheric Administration, Pacific Marine Environmental Laboratory	1974-1984
Affiliate Assistant Professor, University of Washington	1974-1985
Supervisory Oceanographer, National Oceanic and Atmospheric Administration, Pacific Marine Environmental Laboratory	1984-present
Affiliate Associate Professor, University of Washington	1986-present
Affiliate Full Professor, University of Washington	2002-present

c. Publications

(1) Related to proposed research

Feely, R.A., C.L. Sabine, K. Lee, F.J. Millero, M.F. Lamb, D. Greeley, J.L. Bullister, R.M. Key, T.-H. Peng, A. Kozyr, T. Ono, and C.S. Wong (2002): In situ calcium carbonate dissolution in the Pacific Ocean. Global Biogeochem. Cycles, 16(4), 1144, 10.1029/2002GB001866.

Feely, R.A., C.L. Sabine, T. Takahashi, and R. Wanninkhof (2001): Uptake and storage of carbon dioxide in the oceans: The global CO2 survey. Oceanography, 14(4), 18–32.

Gloor, M., N. Gruber, J.L. Sarmiento, C.L. Sabine, R.A. Feely, and C. Rödenbeck (2003): A first estimate of present and preindustrial air-sea CO2 flux patterns based on ocean interior carbon measurements and models. Geophys. Res. Lett., 30(1), 1010, doi:10.1029/2002GL015594..

Lamb, M.F., C.L. Sabine, R.A. Feely, R. Wanninkhof, R.M. Key, G.C. Johnson, F.J. Millero, K. Lee, T.-H. Peng, A. Kozyr, J.L. Bullister, D. Greeley, R.H. Byrne, D.W. Chipman, A.G. Dickson, C. Goyet, P.R. Guenther, M. Ishii, K.M. Johnson, C.D. Keeling, T. Ono, K. Shitashima, B. Tilbrook, T. Takahashi, D.W.R. Wallace, Y.W. Watanabe, C. Winn, and C.S. Wong (2002): Consistency and synthesis of Pacific Ocean CO2 survey data. Deep-Sea Res. II, 49(1–3), 21–58.

Sabine, C.L., R.A. Feely, R.M. Key, J.L. Bullister, F.J. Millero, K. Lee, T.-H. Peng, B. Tilbrook, T. Ono, and C.S. Wong (2002): Distribution of anthropogenic CO2 in the Pacific Ocean. Global Biogeochem. Cycles, 16(4), 1083, 10.1029/2001GB001639.

Other Related Publications

Sabine, C.L., R.M. Key, R.A. Feely, and D. Greeley (2002): Inorganic carbon in the Indian Ocean: Distribution and dissolution processes. Global Biogeochem. Cycles, 16(4), 1067, 10.1029/2002GB001869.

Sabine, C.L. and R.A. Feely (2001): Comparison of recent Indian Ocean anthropogenic CO2 estimates with a historical approach. Global Biogeochem. Cycles, 15(1), 31–42.

Lee, K., R. Wanninkhof, R.A. Feely, F.J. Millero, and T.-H. Peng (2000): Global distribution of total inorganic carbon in surface water. Global Biogeochem. Cycles, 14(3), 979–994.

Millero, F.J., D. Pierrot, K. Lee, R. Wanninkhof, R.A. Feely, C.L. Sabine, R.M. Key, and T. Takahashi (2002): Dissociation constants for carbonic acid determined from field measurements. Deep-Sea

Res. I, 49(10), 1705–1723.

d. Synergistic Activities

Committees

Research Committee, School of Oceanography, University of Washington	1977–1979
Science Policy Board, Pacific Marine Environmental Laboratory, NOAA	1977–1978
NOAA Quality Assurance Committee, NOAA	1983–1984
Scientific Committee on Ocean Research Working Group 75	1984–1988
EPA-WDOE Puget Sound Initiative Technical Advisory Committee	1985–1987
NOAA VENTS Council	1987–1991
U.S. JGOFS Steering Committee	1991–1996
Science Advisory Panel for Climate and Global Change Information Management	1992–2001
Joint Institute for the Study of the Oceans and Atmosphere	1984–present
DOE Science Team for Carbon Measurements	1990–1998
NOAA C02 Science Advisory Panel (Co-chair)	1990–1998
NSF/NOAA Carbon Cycle Working Group	1999–2000
NOAA CO_2 Measurements Advisory Committee	2000–2001
NASA CCI Science Advisory Committee	2001–2002
NACP Drafting Subcommittee	2001–2002
CCSP-Oceans Interim Implementation Committee	2002-2003

Society Memberships

American Association for the Advancement of Science
American Chemical Society
American Geophysical Union
The Oceanography Society

Shipboard Experience

5 cruises in the Gulf of Mexico and Caribbean Sea (120 days at sea).
26 cruises in the North and South Pacific Ocean; 8 cruises as Chief Scientist (557 DAS).
19 cruises in the estuarine and coastal waters of Washington, Oregon and Alaska; 13 cruises as Chief Scientist (247 DAS).

e. Collaborators

W. Balch (Univ. Maine); M. Bender (Princeton); J. Bullister (PMEL); R.H. Byrne (USF); F. Chai (Univ. Maine); R. Dugdale (USF); A. Dickson (UCSD-Scripps); S. Doney (NCAR); C. Goyet (Univ. of Perpignan-France); N. Gruber (UCLA); D. Hansell (BBSR); M. Ishii (MRI-Japan); G. Johnson (PMEL); D. Karl (Univ. Hawaii at Manoa); R. Key (Princeton); K. Lee (Univ. of Miami); C. Measures (UH); F. Millero (Univ. of Miami); R. Najjar (Penn State U.); D. Nelson (OSU); Y. Nojiri (NIES, Japan) T. Ono (NRI-Japan); J. Orr (IPSL – France); T.-H. Peng (AOML); A. Poisson (Univ. of Paris-France); J. Sarmiento (Princeton); T. Takahashi (LDEO); B. Tilbrook (CSIRO-Australia); D. Wallace (IFM-Kiel, Germany); R. Wanninkhof (AOML); R. Weiss (UCSD-Scripps); F. Wilkerson ((USF); C.S. Wong (IOS-Canada)

Vitae **Alexander Kozyr**

Present Address:
10715 Eagle Glen Drive
Knoxville, Tennessee 37922
(865) 966-9900

a. Experience:

1993-present **Research Staff, Ocean Data Analyst**, Carbon Dioxide Information Analysis Center (CDIAC), Environmental Sciences Division, Oak Ridge National Laboratory (ORNL), U.S. Department of Energy, Oak Ridge, Tennessee, and Research Scientist, Energy, Environment, and Resources Center, University of Tennessee, Knoxville and ORNL/CDIAC.

Identifying and obtaining oceanographic data sets that contain CO_2-related measurements resulting from the World Ocean Circulation Experiment (WOCE), Joint Global Ocean Flux Study (JGOFS), and other national and international program cruises. Detailed analyzing and quality assurance (QA) of each particular data set by use of special software, FORTRAN, Unix, and Linux codes. The data are packaged with QA summaries, background information, information about methods and instrumentation used to obtain the data, and file descriptions, and published as Numeric Data Packages (NDPs). Designed and developed a WWW page for CDIAC ocean carbon dioxide (CO_2) project (http://cdiac.esd.ornl.gov/oceans/home.html). Developed on-line publications for all oceanographic NDPs. Participated in the International UNESCO/IOC Global Underway pCO_2 Measurements Program. Participated in UNESCO/IOC CO_2 Panel annual meetings, The Oceanography Society annual meetings, and U.S. Ocean CO_2 Science Team meetings. Involved in the DOE/NOAA funded Global Carbon Data Synthesis Project (GLODAP). Involved in the International Carbon in North Atlantic (CARINA) data synthesis project and serving as a co-chairman of this project. Involved in the North Pacific Organization (PICES) data management support for the carbon-related measurements. Developed the largest data base in the World for the ocean discrete and underway CO_2-related measurements. Participated in the WOCE Indian Ocean (1995) and Antarctic (2001) Oceanographic cruises.

1979-1991 **Scientist-Oceanographer, Senior Scientist-Oceanographer, Oceanographic Group Leader,** Oceanography Department, Sakhalin Administration of Hydrometeorological Service, Sakhalin Island, Russia.

Participated in seventeen Oceanographic Expeditions in Sea of Okhotsk, Pacific and Indian Oceans. Determined and analyzed the hydrographic data obtained during these expeditions. Determined ice conditions, surface temperature, and sea water pollution from aircraft. Developed and published the Atlas of Ice

Conditions in Sea of Okhotsk and Northern Sea of Japan based on long term observations. Coordinated and planned oceanographic expeditions and supervised a team of oceanographers performing the job.

b. Education:

1979 **M.S., Physical Oceanography,** Leningrad Nautical University, USSR. Specialties: Physical and chemical oceanography, marine meteorology and ecology, hydrology of land.

c. Languages:

English, Russian, Ukrainian.

d. Society Affiliation:

The Oceanography Society.

e. Awards:

1993 **Exceptional Public Service Award** for exceptional service to the global change research community worldwide, and significant contribution to the success of the Department of Energy's Global Change research Program, by the US Department of Energy.

1995 **Technical Communication Award** in recognition of achievement in publications for technical reports, by the East Tennessee Chapter of the Society for Technical Communications.

1995 **Certificate of Appreciation** for outstanding contributions in the collection, analysis, coordination, and dissemination of Global Change information, by the US Department of Energy.

1998 **Award of Excellence** for contributing to the technical communication profession via the production of on-line publication, by the Atlanta Chapter of the Society for Technical Communication in the 1997 Online Communications Competition.

1999 **Technical Communication Award** in recognition of achievement in publications for technical reports, by the East Tennessee Chapter of the Society for Technical Communications.

f. Resent Publications:

Feely, R.A., C.L. Sabine, K. Lee, F.J. Millero, M.F. Lamb, D. Greeley, J.L. Bullister, R.M. Key, T.-H. Peng, A. Kozyr, T. Ono, and C.S. Wong 2002. In situ calcium carbonate dissolution in the Pacific Ocean. *Global Biogeochem. Cycles*, 16(4), 1144

Lamb, M.F., C.L. Sabine, R.A. Feely, R. Wanninkhof, R.M. Key, G.C. Johnson, F.J. Millero, K. Lee, T.-H. Peng, A. Kozyr, J.L. Bullister, D. Greeley, R.H. Byrne, D.W. Chipman, A.G. Dickson, C. Goyet, P.R. Guenther, M. Ishii, K.M. Johnson, C.D. Keeling, T. Ono, K. Shitashima, B. Tilbrook, T. Takahashi, D.W.R. Wallace, Y. Watanabe, C. Winn, and C.S. Wong (2002): Consistency and synthesis of Pacific Ocean CO_2 survey data, *Deep-Sea Research II, 49*, 21-58

Tsung-Hung Peng:

a. Professional Preparation

National Taiwan University	Geosciences	B.S., 1966
Columbia University	Geochemistry	Ph.D., 1973
Lamont-Doherty Earth Observatory	Chemical Oceanography	Post-doc.1973-1975

b. Appointments

Oceanographer, Ocean Chemistry Division, NOAA/AOML, Miami, FL. 1995 to present.
Adjunct Professor, Marine and Atmospheric Chemistry, RSMAS, University of Miami, 1997 to present.
Visiting Professor, College of Marine Chemistry, Ocean University of China, Qingdao, China, 2002 to 2005.
Senior Research Staff Member, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN. 1992 to 1994

Research Staff Member, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN. 1981 to 1991.

Research Associate, Lamont-Doherty Geological Observatory of Columbia University, Palisades, NY. 1975-1980.

c. Synergistic Activities

Member, U.S. Joint Global Ocean Flux Study Steering Committee (1991-1994)
Member, U.S. D.O.E. CO2 Survey Science Team (1992-1995)

d. Selected Publications relevant to this proposal

Peng, T.-H., R. Wanninkhof, J. Bullister, R. Feely, and T. Takahashi, 1998. Quantification of decadal anthropogenic CO2 uptake in the Ocean based on dissolved inorganic carbon measurements, Nature 396:560-563.

Peng, T.-H., R. Key, and H. G. Ostlund, 1998. Temporal variations of bomb radiocarbon inventory in the Pacific Ocean. Marine Chemistry, 60, 3-14.

Broecker, W. S. and T.-H. Peng, 1998. **GREENHOUSE PUZZLES**, Rev. Edition, Eldigio Press, Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York. 277pp.

Peng, T.-H., J.-J. Hung, R. Wanninkhof, and F. J. Millero, 1999. Carbon budget in the East China Sea in spring, Tellus, 51B, 531-540.

Broecker, W.S., C. Langdon, T. Takahasi, and T.-H. PENG, 2001. Factors controlling the rate of $CaCO_3$ precipitation on Great Bahama Bank. *Global Biogeochemical Cycles,* 15(3):589-596.

Peng, T-H and F. Chai. 2002. Modeling the carbon cycle in the Equatorial Pacific Ocean. In: Marine Environment; The Past, Present and Future, edited by C.H. Chen, p240-255.

Chai, F., R.C. Dugdale, T-H Peng, F.P. Wilerson, and R.T. Barber, 2002. One dimensional ecosystem model of the equatorial Pacific upwelling system, Part I: Model development and silicon and nitrogen cycle, Deep-Sea Research II , 49, 2713-2746.

Dugdale, R.C., R. Barber, F. Chai, T.H. Peng, and F.P. Wilkerson, 2002. One dimensional ecosystem model of the equatorial Pacific upwelling system, Part II: Sensitivity of the model parameters and comparison with nutrient conditions during the JGOFS EqPac cruises in 1992, Deep-Sea Research II , 49, 2747-2968.

Dugdale, R. C., A. G. Wischmeyer, F.P. Wilkerson, R.T. Barber, F. Chai, M. Jiang, and T.-H. Peng. 2002. Source of meridional asymmetry of nutrients to the equatorial upwelling ecosystem and modeling of the impact on ocean-atmosphere CO2 flux, Deep-Sea Research II, 49, 2513-2532.

Feely, R.A., C.L. Sabine, K. Lee, F.J. Millero, M.F. Lamb, D. Greeley, J.L. Bullister, R.M. Key, T.-H. Peng, A. Kozyr, T. Ono, and C.S. Wong, In situ calcium carbonate dissolution in the Pacific Ocean. *Global Biogeochem. Cycles,* 16(4), 1144, 10.1029/2002GB001866, 2003.

Sabine, C. L., R. A. Feely, R. M. Key, J. L. Bullister, F. J. Millero, K. Lee, T.-H. Peng, B. Tilbrook, T. Ono, and C. S. Wang, 2002. Distribution of anthropogenic CO_2 in the Pacific Ocean, *Global Biogeochem. Cycles*, 16, 1083, doi10.1029/2001GB001639.

Lamb, M.F., C.L. Sabine, R.A. Feely, R. Wanninkhof, R.M. Key, G.C. Johnson, F.J. Millero, K. Lee, T-H Peng, A. Kozyr, etc., 2002. Consistency and synthesis of Pacific Ocean CO2 survey data. Deep-Sea Research II 49, 21-58.

Li, Y.-H. and T.-H. Peng, 2002. Latitudinal changes of remineralization ratios in the oceans and its implication for nutrient cycles, 16, No. 4, 1130, doi:10.1029/2001GB001828.

Liu, K.-K., T.-H. Peng, and P.-T. Shaw, 2003. Circulation and biogeochemical processes in the East China Sea and the vicinity of Taiwan: An overview and a brief synthesis. Deep-Sea Res. Part II, 50, 1055-1064.

Peng, T.-H., R. Wanninkhof and R. A. Feely, 2003. Increase of anthropogenic CO_2 in the Pacific Ocean over the last two decades, Deep-Sea Res. Part II, (in press).

CURRENT AND PENDING SUPPORT:
Steve Hankin, NOAA/PMEL

Current
"Support for the US GODAE Server in Monterey"
Office of Naval Research
10/1/01-9/30/04 PMEL support: $437K PI months: 1.5 ('04)

"Integrating Web Services: Bi-directional Coupling of OPeNDAP (DODS) and LAS"
NOAA/HPCC
3/1/03-2/28/04 PMEL support: $75K PI months: 0.25 ('04)

"A Thematic Data Portal to Satellite-Derived Ocean Surface Properties: Discovery and Access"
NASA CAN-02-OES-01
04/1/04-03/31/08 PMEL support: $549 PI months: 2,2,2,2,2 ('04-'08)

Global Ocean Predication with the HYbrid Coordinate Ocean Model (HYCOM)
National Ocean Partnership Program – GODAE BAA Dec. 2002
10/1/03-09/30/06 PMEL support: $484 PI months: 1,1,1 ('04-'06)

"Continuation of Collaborative Data Server System Development with the IPRC in support of GODAE" NOAA/OGP
10/1/03 – 9/30/04 Project support: $50K PI months: 0.5

Pending
"Ocean Web Portal"
NASA NRA-02-OES-04
04/1/03-03/31/06 PMEL support: $88 PI months: .5,.5,.5 ('04-'06)

CURRENT AND PENDING SUPPORT

Richard A. Feely - NOAA/PMEL
Feely is a full time federal employee and is not eligible for salary support from extramural proposals, therefore, none of the current or pending proposals include salary support for him.

***CURRENT SUPPORT*:**

Title: Data Synthesis for the WOCE Indian Ocean and Atlantic Ocean Radiocarbon Programs
Supporting Agency: National Science Foundation: OCE-9986310
Person-month/year: 5
Amount: $370,000
Duration: 04/01/00 - 09/30/03
Location: Princeton University, Sayre Hall, Forrestal Campus

Title: Production, Transport and Dissolution of Calcium Carbonate in the Global Ocean: A Synthesis and Modeling Project.
Supporting Agency: National Science Foundation
Person-month/year: 1
Amount: No funding for PMEL
Duration: 04/01/02 - 03/31/04

Title: Collaborative Research: Global Ocean Repeat Hydrography, Carbon, and Tracer Measurements
Supporting Agency: NOAA
Person-month/year: 2
Amount: $875,678
Duration: 9/01/02 - 8/31/07

Title: Initial Steps Towards a Global Surface Water pCO_2 Observing System
Supporting Agency: NOAA
Person-month/year: 2
Amount: $ 499.000
Duration: 10/01/02 - 9/30/05

Title: Phytoplankton dynamics and carbon cycling in the Equatorial Pacific Ocean: Control by Si and Fe
Supporting Agency: NSF
Person-month/year: 1
Amount: $120,000
Duration: 12/01/04 - 9/31/07

Title: Underway CO_2 Measurements on the NOAA Ships *Ka'imimoana*, *Ron Brown*, *Palmer*, and *Explorer of the Seas*.

Supporting Agency: NOAA
Person-month/year: 1
Amount: $355,389
Duration: 9/01/02 - 9/30/04

PENDING SUPPORT:

Title: Satellite-based Quantification of Air-Sea Exchange of CO_2.
Supporting Agency: NASA/EOS/IDS
Person-month/year: 1
Amount: $287,461
Duration: 10/01/03 - 9/30/06

Current and Pending Support:
Tsung-Hung Peng, NOAA/AOML

Note:

1. T-H Peng is a full time federal employee and is not eligible for salary support from extramural proposals- therefore none of the proposals include salary support for him.
2. The pending support does not include the proposals being submitted to the NOAA/OGP/GCC announcement.

***CURRENT SUPPORT*:**

Title: Collaborative Research: Biogeochemical Modeling of Carbon Partitioning in the Pacific: the Role of Si and Fe in Regulating Production by Siliceous and Calcifying Phytoplankton.
Supporting Agency: NSF
Person-month/year: 1
Amount: $83,000 (to Peng through RSMAS, U. of Miami)
Duration: 03/01/02 - 02/28/05
Location: AOML

Title: Penetration of Anthropogenic CO_2 in the oceans based on analysis of recent WOCE/JGOFS/OACES Carbon Data Using the Remineralization Ratios Obtained By the New Three-End-Member Mixing Model.
Supporting Agency: NOAA/OGP/GCC
Person-month/year: 3
Amount: $227,500
Duration: 09/01/02 - 08/31/05
Location: AOML